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ABSTRACT

Statistical interactions between two instructional methods and five cognitive aptitudes were examined to determine whether the methods are most effective among different learners. Sixth grade students (n=275) were randomly assigned to eight periods of rule-example (ruleg) or example-rule (egrule) programmed instruction in critical thinking. Aptitude tests measured reasoning abilities, conceptual styles, conceptual levels, and two kinds of formal operations. Criterion instruments measured recall, retention and attitudes. Seven significant disordinal aptitude-treatment interactions were observed. Ruleg and egrule methods were consistently most effective among high and low scorers, respectively. Deductive reasoning ability provided the most valid and consistent grounds for differentiating instruction among different students. (Author)

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Interactions Between Aptitudes and Instructional Strategies

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Main effects and statistical interactions between two instructional strategies and five intellectual aptitudes were examined among 275 sixth grade students. This report outlines the purposes, theroetical framework, methods, results and implications of the experimental study.

Purposes. The study was designed to determine whether two prominent teaching methods yield different mean levels of effectiveness, or whether they are most appropriate for different learners. Significant findings promised to indicate whether teachers should adopt either method exclusively, or use the two methods among different students. Secondary purposes of the study were to determine the factor loadings and construct validity of five aptitude tests, and the cognitive requirements of two widely used instructional strategies.

Theoretical Framework. In recent years many innovative schools have reorganized their class schedules, their use of space, their procedures for grouping staff and students, and their procedures for administrative and instructional decision-making. Each reform has created opportunities for instructors to vary their teaching among pupils, without suggesting how to do so. Nearly all concepts or patterns of individualized instruction focus on variations in the content, difficulty or pace of instruction. Reformers have given relatively little attention to individual variations in the methods of instruction. To determine whether different students learn most effectively

during different instructional methods, it is necessary to examine statistical interactions between aptitudes and teaching strategies. Significant disordinal interactions suggest that different strategies work best among learners who are at opposite ends of a trait distribution.

As the treatment factor, the sequence of instructional tasks was selected for examination, because task sequence is a fundamental attribute of all teaching methods. In one treatment condition, abstract concepts and processes were described before examples and nonexamples were presented. In the other, examples and nonexamples appeared first, and students were required to formulate the abstractions.

Ruleg (rule-example) and egrule (example-rule) strategies were investigated because they are equally appropriate for teaching concepts and processes and they are equally expensive and difficult for teachers to adopt. They also correspond to expository and discovery methods, which are widely used and advocated. Furthermore, ruleg and egrule depend on different intellectual traits among learners. During ruleg instruction, abstract descriptions must be analyzed and applied deductively to specific problems. To succeed in the egrule condition, students must rely on themselves to generate abstract principles inductively, by comparing individual examples and nonexamples and testing hypotheses regarding their similarities and differences. Finally, ruleg and egrule were examined because they interacted disordinally with several aptitude dimensions in previous studies (Wright, 1975).

Aptitude variables were operationally defined as scores on five group tests: Raven's Progressive Matrices (RPM), the Group Embedded Figures Test (EFT), the Conceptual Levels Test (CLT), and two Formal Operations Tests called the Probabilities Test (FOT-P) and the Logic of Propositions Test (FOT-LP). Scores from each test were expected hypothetically to interact with

ruleg and egrule treatments. Either strategy could be most effective among high or low RPM scorers, since RPM taps both deductive and inductive reasoning abilities. A second reason for including RPM in the design was that ruleg and egrule treatments interacted with other intelligence test scores in several earlier investigations. Again, however, different studies yielded interactions in opposite directions, making the direction of interaction impossible to predict.

Ruleg or egrule treatments were also expected to be most effective among high or low EFT scorers, again depending on this test's construct validity. Witkin (1975) has hypothesized that individual differences in field dependence should interact with variations in the degree of structure in learning tasks. To solve many kinds of problems, he argued, analytic persons generate mediating concepts more effectively than field dependent or global individuals. For example, analytics characteristically organize instructional tasks, and are therefore likely to have an advantage in learning them. Mediating concepts are not needed to learn inherently structured or organized tasks, however, so analytics and globals are likely to learn these tasks equally. If these predictions are correct, EFT scores should interact with treatments that reflect different degrees of task structure, and high scorers should learn significantly more than low scorers from egrule, since verbal definitions of concepts (mediators) are lacking only in egrule instruction. If the EFT measures analytic ability, however, highs could also be expected to learn most from ruleg instruction, which relies on learners to analyze complex, abstract concepts at the outset. Lows, similarly, could be expected to benefit most from egrule, which requires that students synthesize together the preanalyzed elements of a complex concept. Again the direction of the anticipated interaction depended on an aptitude test's construct validity.

Ruleg and egrule strategies were also expected to suit low and high CLT scorers, respectively, since they were regarded as having high and low degrees of task structure, and since similar treatments had interacted with CLT scores in previous experiments (Hunt, 1971). Finally, ruleg was hypothesized to be more abstract and symbolic than the egrule treatment. Consequently, ruleg and egrule were expected to work most effectively among high and low FOT scorers, respectively, on the widespread assumption that abstractness and concreteness suit formal and pre-formal operators.

Methods. Subjects were sixth grade students (n=369) in three California school districts. Classroom teachers volunteered to participate, usually because of interest in the topic of instruction. Participating school districts serve communities that are predominantly professional, commercial and industrial. A no-treatment control group (n=94) was formed by randomly selecting one intact classroom from each district. The remaining ten intact classrooms constituted the experimental group (n=275). Individual students in the experimental group were randomly assigned to ruleg (n=130) and egrule (n=145) treatments.

Elementary concepts and processes of critical thinking formed the content of instruction. Students learned to apply four cognitive operations to eight kinds of logical and illogical reasoning. They discriminated between instances of logical and illogical reasoning, identified the fallacies in illogical instances, discriminated between critical and uncritical responses to fallacies, and formulated their own critical responses. They performed these operations in response to examples and nonexamples of over-generalizations, over-simplifications, invalid inferences, insufficient explanations, incomplete analogies, unreliable authorities, purely emotional appeals and purely personal considerations.

In order to control instructional variables, programmed booklets were used as the medium of instruction. Ruleg and egrule strategies were incorporated in separate sets of instructional booklets. Subjects in the ruleg group read concept definitions, discriminated between examples and nonexamples of the concepts, and defined the concepts themselves. They also read explanations of the cognitive operations, discriminated between valid and invalid applications of the operations, and performed and explained the operations. Egrule booklets contained the same tasks, except concept definitions and process explanations. Table 1 shows a detailed analysis of each ruleg and egrule sequence. Both sets of booklets contained the same concepts, processes, examples, nonexamples, task instructions, number of tasks, and number of examples and nonexamples.

Four criterion-referenced achievement tests and an attitude questionnaire were developed to serve as criterion instruments in the study. During each achievement test students performed the same intellectual operations in response to the same kinds of examples and nonexamples as they had during instruction. Reliability coefficients ranged from .67 to .77 (parallel forms). The questionnaire measured children's attitudes toward critical thinkers, the value of critical thinking, their own capacities to think critically, and the prospect of studying the topic further. Its reliability was .67 (retest).

Instruction occurred in daily, forty minute periods for two weeks. Ruleg and egrule booklets were used individually by students in intact classrooms. Teachers administered the aptitude tests, the pretest and the questionnaire before instruction began, posttests at the end of each week, and a third posttest and the questionnaire one week after instruction ended.

Results. Pearson product-moment correlation coefficients among the five aptitude tests, in Table 2, suggested they were strongly and positively related to each other. The varimax rotated factor matrix in Table 3, however, established that the tests tapped relatively discrete intellectual factors. A second factor analysis (available on request) also showed that separate factors accounted for scores from the four achievement tests. For this reason, scores from each aptitude and achievement test were examined separately in subsequent analyses.

Analysis of variance in pretest, prequestionnaire and aptitude test scores (Table 4) showed no significant (.05) initial differences between ruleg and egrule treatment groups. These scores were not, therefore, used as covariates in the analysis of treatment effects. Similar analyses of criterion scores indicated that achievement test scores were significantly higher after the experimental treatments than after the no-treatment control condition (Table 5). Furthermore, ruleg instruction yielded moderately higher achievement test scores, and significantly more positive attitudes among students, than egrule instruction (Table 6). As a general rule, then, ruleg or deductive instruction proved to be more effective than egrule or discovery teaching. But what of individual differences? Did the alternative instructional strategies interact with aptitude test scores?

To examine interaction effects, the F-distribution was used to assess the strength of differences between ruleg and egrule regression slopes. The consequences of a Type I error were regarded as less serious than those of a Type II error, so $p=.20$ was selected as the test of significance. In seven significant, disordinal interactions, ruleg and egrule strategies were most effective among high and low aptitude test scorers, respectively. Using the Johnson-Neyman equation, significance regions were

computed to determine which individuals benefited significantly (.05) more from either teaching strategy than the other. Only the regression of achievement test scores on RPM scores yielded separate regions in which ruleg and egrule, respectively, were significantly more effective than the other. EFT and CLT scorers also generated regions in which ruleg instruction was significantly superior to egrule instruction. Only RPM scores identified students for whom egrule was significantly better than ruleg. Figures 1-7 depict regression functions and confidence limits for the seven significant interaction effects.

Implications. Instruction in elementary concepts and processes of critical thinking was clearly effective among sixth grade children who participated in the study. It made relatively little difference, however, whether programmed instruction presented rules before examples, or examples before rules. Mean achievement test scores were consistently (but not significantly) higher after the rule-example sequence than after the example-rule sequence. The former strategy also yielded significantly more positive pupil attitudes toward critical thinking than the latter strategy. On the basis of these findings, programmed instruction in critical thinking should generally follow a deductive sequence from rules to examples.

Seven observed interactions provide grounds for teaching elements of critical thinking differently among different students. Raven's Progressive Matices (RPM) indicate which students learn most from rule-example instruction, and which ones benefit most from example-rule instruction. Four other aptitude tests consistently lacked this predictive validity. Decision rules for differentiating instructional methods among students were shown to depend on the objectives of instruction. Students whose RPM scores are above and below 26, 28 and 18 should receive ruleg and egrule instruction, respectively, depending on whether immediate recall, delayed retention or attitudes are of primary

interest. Questionnaire responses, moreover, consistently obscured interactions that emerged from achievement test scores. In fact, observed interactions between aptitudes and instructional methods were usually specific to particular criterion factors.

The direction of observed interactions illuminates the task requirements of ruleg and egrule treatments, and the construct validity of five aptitude tests. Students who learned most from deductive (ruleg) instruction also scored higher on RPM than children who learned most from inductive (egrule) teaching. Deductive reasoning, then, probably plays a more prominent role in solving RPM items than inductive abilities. EFT, CLT and FOT scores were expected to interact with the psychological requirements of initial ruleg and egrule tasks. Relatively weak observed interactions suggest that differences in the complexity, structure and abstractness of initial ruleg and egrule tasks are less important differences than the inductive-deductive contrast. For this reason, individual differences in reasoning abilities provide more valid grounds than cognitive styles, conceptual levels or levels of intellectual development for deciding which students should receive rule-example or example-rule instructional sequences.

Table 1

Task Sequences in Ruleg and Egrule Treatments

Ruleg Treatment Tasks	Egrule Treatment Tasks
1. Rule. Read a definition of a Set 1 concept.	Tuning. Read an introduction to the inductive task ahead.
2. Mediation. Read an explanation of the concept's name.	Observation. Same as Ruleg #3.
3. Observation. Read four examples of the concept.	Observation. Same as Ruleg #4.
4. Observation. Read a mixed list of four Set 1 and Set 2 examples. Note which items are identified as Set 1.	Discrimination. Same as Ruleg #5.
5. Discrimination. Read four Set 1 examples paired with four Set 2 examples. Mark Set 1 examples.	Feedback. Same as Ruleg #6.
6. Feedback. Compare responses to #5 with correct ones.	Discrimination. Same as Ruleg #7.
7. Discrimination. Read a mixed list of four Set 1 and Set 2 examples. Mark the Set 1 examples.	Feedback. Same as Ruleg #8.
8. Feedback. Compare responses to #7 with correct responses.	Rule. Attempt to define the Set 1 concept in writing.
9. Recall. Define the Set 1 concept in writing.	Feedback. Same as Ruleg #10.
10. Feedback. Compare definition with model definition.	Mediation. Same as Ruleg #2.
11. Association. Read a mixed list of four Set 1 and Set 2 examples. Write concept name beside Set 1 examples.	Association. Same as Ruleg #11.
12. Feedback. Compare responses with correct responses.	Feedback. Same as Ruleg #12.
13. Rule. Read rules for making critical responses to Set 1 examples.	Tuning. Read an introduction to the idea of responding to fallacies.
14. Observation. Read critical responses to four Set 1 examples.	Observation. Same as Ruleg #14.
15. Discrimination. Read a mixed list of four critical and uncritical responses. Mark critical responses.	Discrimination. Same as Ruleg #15.
16. Feedback. Compare responses with correct ones.	Feedback. Same as Ruleg #16.
17. Application. Write responses to four Set 1 examples.	Application. Same as Ruleg #17.
18. Feedback. Compare responses to #17 with model responses.	Feedback. Same as Ruleg #18.
19. Recall. Write the rules for making critical responses to Set 1 examples.	Rule. Attempt to state in writing the rules for making critical responses to Set 1 examples.
20. Feedback. Compare response to #19 with model response.	Feedback. Same as Ruleg #20.

Table 2

Correlations Among Aptitude Test Scores

	EFT	CLT	FOT-P	FOT-LP
RPM Scores	.51	.21	.43	.56
EFT Scores		.14	.47	.46
CLT Scores			.25	.26
FOT-P Scores				.53

Table 3

Factor Matrix: Aptitude Test Scores

Subtests	Factor 1	Factor 2	Factor 3	Factor 4
RPM Set A	.02	.66	.13	.16
RPM Set B	.09	.78	.25	.22
RPM Set C	.10	.66	.38	.23
EFT Part 1	.04	.28	.06	.53
EFT Part 2	.09	.18	.34	.77
EFT Part 3	.00	.17	.41	.71
CLT Average 1	.93	.09	.18	.01
CLT Average 2	.93	.08	.20	.06
FOT-P Total	.13	.21	.58	.25
FOT-LP Total	.12	.39	.64	.17

Table 4

Analysis of Variance in Aptitude & Pretest Scores:
Ruleg vs. Egrule Groups

Tests	Means R	Means E	Standard Deviations R	Standard Deviations E	F	p
RPM	28.56	28.41	5.21	6.39	0.05	.827
EFT	11.76	12.83	5.69	5.42	2.53	.113
CLT	1.17	1.26	0.41	0.42	3.09	.080
FOT-P	4.91	4.86	2.38	2.21	0.04	.850
FOT-LP	5.67	5.50	2.53	2.50	2.30	.586
Pretest	33.68	33.70	11.71	11.07	0.00	.989
Preques	3.04	3.19	0.96	0.90	1.73	.189

Table 5

Analysis of Variance in Criterion Scores:
Experimental vs. Control Groups

Tests	Means R	Means E	Standard Deviations R	Standard Deviations E	F	p
Test 1	50.65	39.52	15.91	11.47	38.92	.000
Test 2	54.69	42.31	18.68	13.29	35.14	.000
Test 3	44.69	35.20	17.02	13.07	24.27	.000
Postques	3.31	3.50	1.04	0.97	4.73	.111

Table 6

Analysis of Variance in Criterion Scores:
Ruleg vs. Egrule Groups

Tests	Means R	Means E	Standard Deviations R	Standard Deviations E	F	p
Test 1	51.91	49.52	16.94	14.91	1.55	.214
Test 2	55.73	53.76	19.15	18.25	0.76	.383
Test 3	45.02	44.41	17.67	16.48	0.09	.768
Postques	3.14	3.46	1.04	1.03	6.64	.010

Figure 1: Regression of
Test One Scores on RPM Scores

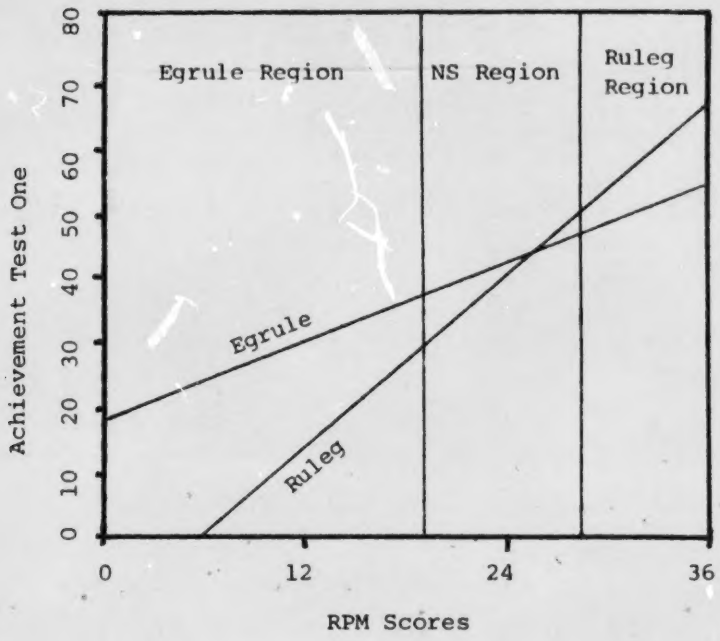


Figure 2: Regression of
Test Two Scores on RPM Scores

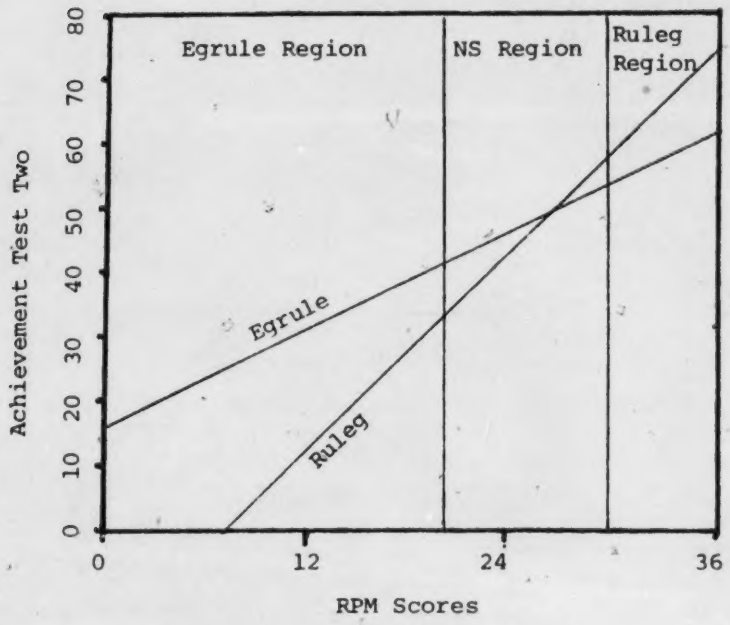


Figure 3: Regression of
Test Three Scores on RPM Scores

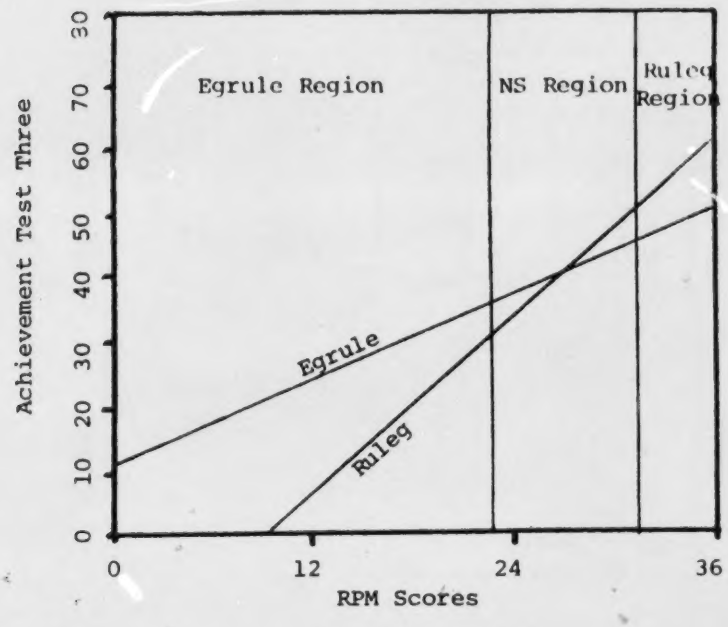


Figure 4: Regression of
Questionnaire Responses on RPM Scores

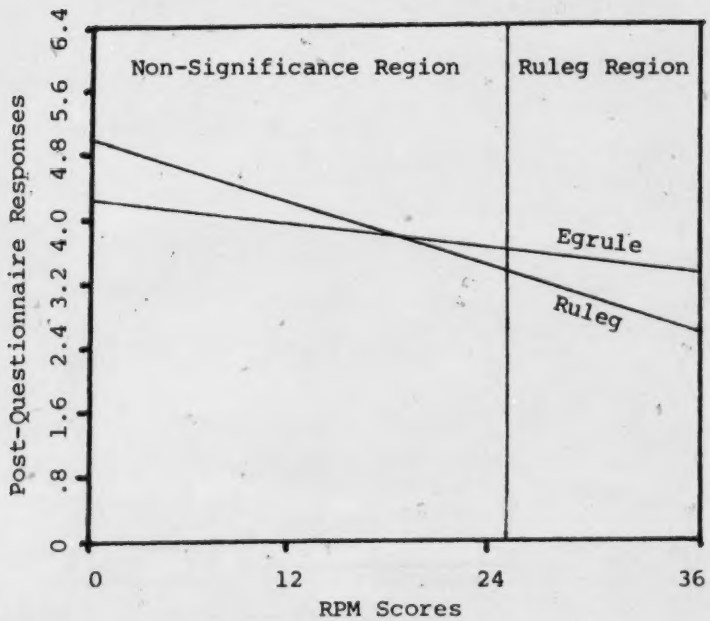


Figure 5: Regression of
Test One Scores on EFT Scores

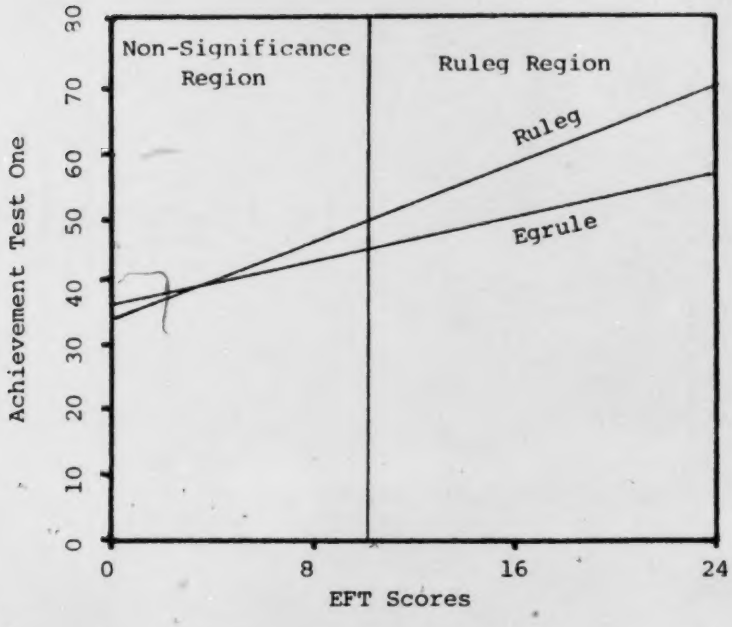


Figure 6: Regression of
Test Three Scores on CLT Scores

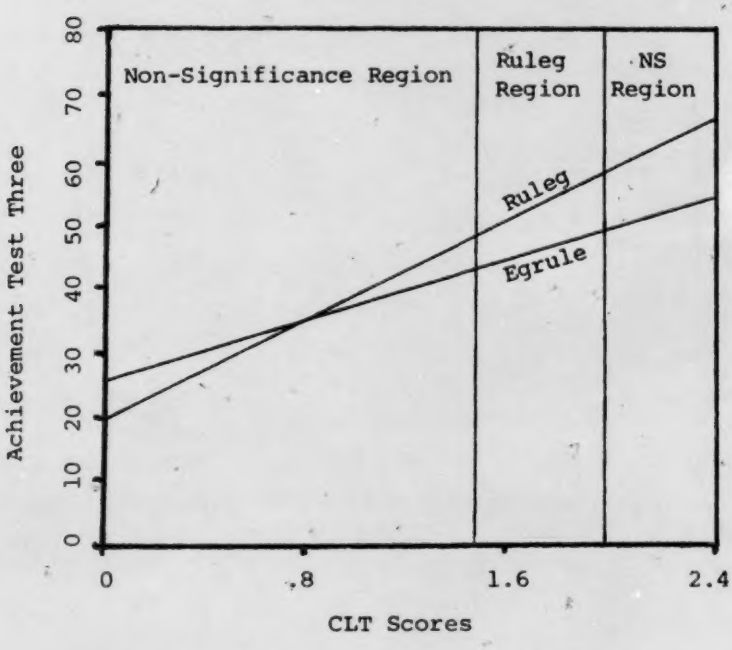
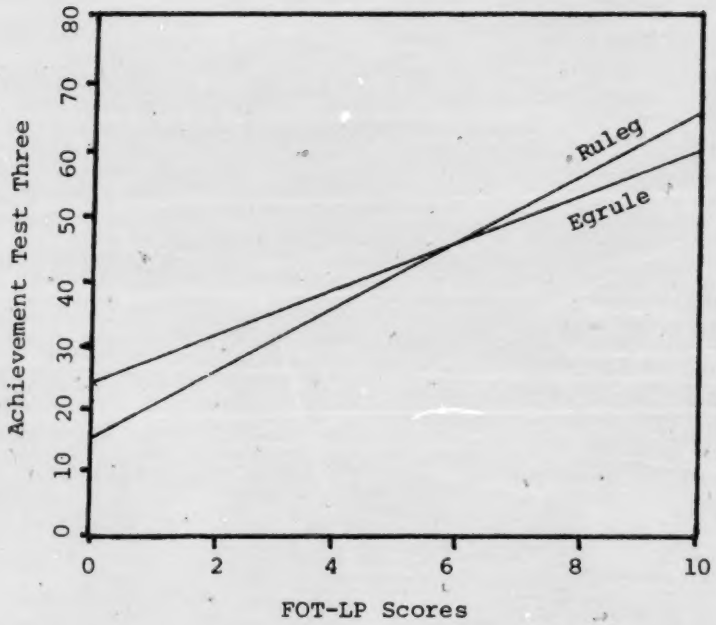


Figure 7: Regression of
Test Three Scores on FOT-LP Scores



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